Usefulness of AIRS-Derived OLR, Temperature, Water vapor and Cloudiness Anomaly Timeseries for GCM Validation

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GC41B-0894

Motivation:

In the beginning, a good measure of a GMCs performance was their ability to simulate the observed mean seasonal cycle. Here, a reasonable simulation of the means (i. e., small biases) and standard deviations would suffice. More recently, Reichler and Kim [2008] argued for a complex but single "Performance Index P" to estimate the reliability of coupled GCM simulations of TODAY'S climate.

Here, we argue that coupled GCM (CGCM for short) simulations of FUTURE climates should be evaluated in much more detail, both spatially and temporally. Moreover, it is NOT the bias, but the anomaly timeseries as well as the average rate of change (see definition below) of these timeseries which really matter. This statement is underlined by the social need to address potential REGIONAL climate variability, and climate drifts/changes in a manner suitable for policy decisions.

Important Definitions for this presentation:

"Average Rate of Change" or **ARC** is defined as the slope of a linear regression which fits the ***monthly anomaly*** (the difference of the value for that month from its climatology, the length of which is dependent on the length of the simulation we want to compare with observations) ***timeseries*** of a given variable. Here, the spatially smallest ARC is computed on a gridpoint-by-gridpoint (*e. g.*, 1°x1°) scale, whilst the largest one is for the global scale. The ***REGIONAL*** [the area mean ARC is the cosine latitude weighted ARC over the area] scale, the most important for climate change predictions, falls in-between, so *a **gridpoint-by-gridpoint ARC-map is a great tool to assess possible regional climate variability/changes***. Of course, in addition of evaluating ARCs, the anomaly timeseries (ATs for short) themselves should also be evaluated comparatively. For this purpose, **Hovmöller diagrams** would serve nicely.

Question: What can we learn by comparing observed vs. model-generated ARC-maps and Hovmöller diagrams say for an 8-yr period where we have AIRS analyses as THE observations [which extend to 8+ full years so far]?

Since AIRS provides a consistent and (by now) reasonably validated (in this respect, we also call your attention to the Susskind *et al.* POSTER today **[A43B-202]**) 3-D picture of the atmosphere, we propose here that the AIRS analyses could be THE observations for ATs and ARCs for coupled GCM simulation evaluations/validations.

So, the inferences from the comparisons of model vs. observed ARCs and ATs could be the followings:

A) If a given CGCM-generated ARC-map of an atmospheric variable is correlating well with the corresponding observed ARC-map, we may put more trust into the longer-term (even climatic) trend-computation by *this* CGCM for *this* parameter;
B) It is possible that only certain region(s) correlate well: in this case may trust the CGCM ARCs only for these region(s);
C) No good correlation at all; **THEN** we may conclude:
i) CGCM forcings may be inaccurate;
ii) CGCM feedbacks may be inaccurately parameterized;
iii) Combination of i) and ii).

Note that in case i), we still can intercorrelate ARC and Hovmöller maps of various atmospheric parameters among the observed as well as among the CGCM-generated maps. Say, we find a high correlation (indicating a strong feedback between parameters) between AIRS-observed OLR and 500 hPa Specific Humidity ARC-maps and/or ATs, **AND** the same good correlation is computed between the corresponding CGCM-generated ARC-maps and/or ATs, we may conclude that the CGCM represents this feedback reasonably well. This way we may eliminate ii) and iii) to be the case.

Examples shown on the right:

- *AIRS vs. other observations:*

a) Show AIRS vs. CERES - Note that DESPITE significant bias, the ARC-maps and ATs are VERY similar;
b) Although not shown here, we have found that even the AIRS vs. MODIS effective cloud cover ARCs and ATs are correlating over 0.95, where biases can be are as high as 20-30%!;

- *AIRS-observed interrelations:*

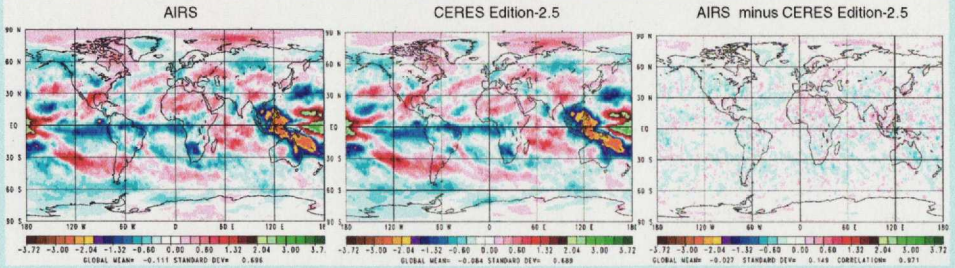
a) how El Niño - La Niña related behavior as seen in ARCs and Hovmöller diagrams and point out various interrelations;
b) Show some numerical values of AIRS ARC-map interrelations (CGCMs should exhibit similar values).

THESE findings indicate the ROBUSTNESS of the AIRS-retrieved ARCs and ATs, so:

- their spatial PATTERNs should serve as benchmarks for the corresponding CGCM-generated patterns;
- their INTERCORRELATIONS could also be reliably used as benchmarks for the corresponding CGCM-generated interrelations, *i. e.*, helping to assess CGCM feedbacks.

Comparison of OLR observations

OLR Anomaly ARCs [W/m²/yr] September 2002 through February 2010



DATA used: **AIRS Version-5** monthly mean data obtained from Goddard DISC (Level 3).
Presented on a 1°x1° latitude-longitude grid
1:30 AM and 1:30 PM monthly mean values extracted separately and averaged together
Data now extends to November 2010

CERES "SSF1" Edition 2.5 monthly mean obtained from Langley ASDC
These data are also presented on a 1°x1° latitude-longitude grid,
but extend to February 2010

Significance of (validated) AIRS OLR

AIRS OLR is a computed product for each AIRS FOR using an OLR RTA

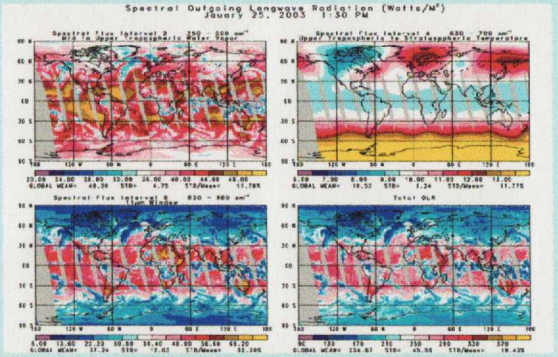
CERES OLR is primarily a measured product

If ATs and ARC-maps of AIRS OLR closely match those of CERES OLR, then:

This validates ATs and ARC-maps of **both** AIRS OLR and CERES OLR;
This indirectly validates ATs and ARC-maps of other AIRS retrieved products (being input 'components' of the AIRS OLR computation);
In addition, ATs and ARC-maps of OLR can now be attributed to those of its component parts

Note: ATs and ARC-maps of AIRS and CERES OLR can match well if there is a bias between AIRS and CERES OLR but it is essentially constant in time.

A side-note for future work: Version-6 of the AIRS-retrieval scheme will provide not just Total OLR but spectral OLR as well (in 16 bands), which will help to evaluate upper tropospheric humidity behavior in CGCMs. See illustration of for 4 spectral bands below for a given day's afternoon orbit.



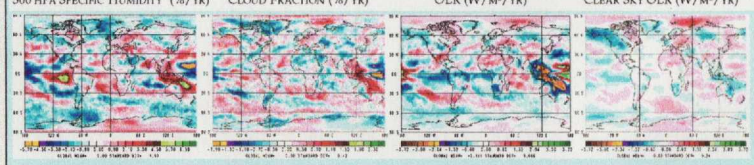
90-Month AIRS Version 5 ARC-map Correlations

	T_{skin}	LWCRF	$PCSH_{500}$	OLR_{CLR}	OLR	A_{eff}
T_{skin}	----	-0.16	0.12	0.70	0.17	0.14
LWCRF	-0.45	----	-0.55	0.19	0.91	-0.76
$PCSH_{500}$	0.31	-0.69	----	-0.20	-0.54	0.41
OLR_{CLR}	-0.02	0.60	-0.74	----	0.58	-0.16
OLR	-0.39	0.98	-0.75	0.74	----	-0.70
A_{eff}	0.29	-0.89	0.63	-0.67	-0.90	----

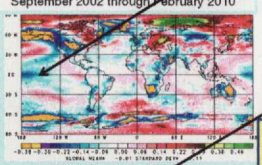
RED: Global Spatial Correlations
Black: Tropical {20°N-20°S} Spatial correlations
We also show correlation for the longwave cloud radiative forcing [LWCRF] here for its importance in GCM simulation evaluations

Can, for example, CGCMs "see" Effects of El Niño on OLR and other parameters??

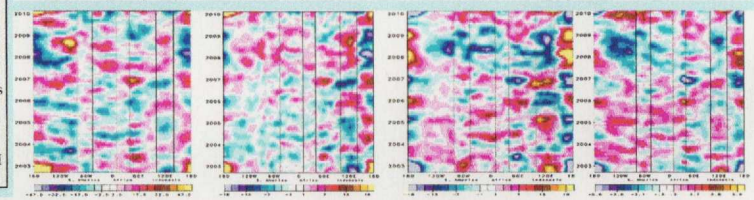
AIRS Anomaly ARCs September 2002 through February 2010

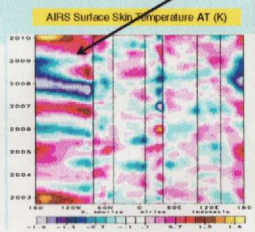


Surface Skin Temperature ARC-map (°K/yr) September 2002 through February 2010



Hovmoller Diagrams of AIRS Monthly Anomalies Sept. 2002 through Feb. 2010 for the Deep Tropics (5N to 5S)





CGCM simulations should also find:

A negative tropical zonal mean trend exists during the period September 2002 through 2010 for the fields of OLR, Clear Sky OLR and Surface Skin Temperature.

A strong equatorial SST cooling trend exists from 160E to 120W surrounded by a weaker warming ring to the west. A transition occurred from a strong El Niño in late 2002 to a strong La Niña in 2008. Late 2009 is characterized by the beginning of another El Niño.

Trends in 500mb specific humidity and cloud cover are in phase with those of SST in the El Niño and surrounding region causing OLR to decrease significantly near the dateline and increase in the vicinity of Indonesia. Tropical OLR trends in these two areas approximately cancel each other.

The negative zonal mean tropical OLR trend results from a drop in equatorial OLR from 150W to 30E . This results from increasing water vapor and cloud cover in this area during La Niña. Roughly 2/3 of the decrease in tropical OLR results from a decrease in cloud cover and 1/3 from a decrease in water vapor. (See Poster **A43-202** for more detailed explanations, regional

Conclusions:

- The ***ROBUST*** nature (biases are not as important as previous GCM-evaluations suggest) of the AIRS-observations-generated ARC-maps and ATs as well as their interrelations suggest that they could be a useful tool to select CGCMs which may be considered the reliable, *i. e.,* to be trusted even for longer-term climate drift/change predictions (even on the regional scale).
- Get monthly gridded CGCM timeseries of atmospheric variables coinciding with the timeframe of the AIRS analyses for at least 5-6 years and do the actual evaluations of ARC-maps and ATs for the coinciding time periods. ANY suggestions which CGCM group(s) should we approach to get such timeseries? (see e-mail addresses under the Title)